FERN ENGINEERING, INC

REPORT NO. 5467-08-4

TO

NEWFOUNDLAND POWER CO.

FOR

GAS PATH INSPECTION OF GRAND BANK
MOD POD 25 POWER TURBINE
FOR CONTINUED OPERATION
AT 20 MW AND UNDER

July 29, 2001

Harley D. Plante

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FERN ENGINEERING
EXPERTS IN TURBOMACHINERY

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SYMBOLS, TERMS, AND PHYSICAL ORIENTATION LIST

T6 or EGT = Exhaust gas temperature as measured by the Gas Turbine Inlet Housing thermocouples.
GG = Gas Generator
PT = Power Turbine
SIB = Service Information Bulletins by Curtiss Wright, original manufacturer of PT & supplier of unit.
PIB = Product Improvement Bulletins by Curtiss Wright
TIB = Technical Information Bulletins by Fern Engineering, Current Engineering support of the unit.
MM = Maintenance Manuals by Curtiss Wright
Aircraft convention viewing = back to alternator, eyes towards inlet plenum.
Aircraft convention terms.
Inlet, Forward, Front
Exhaust, outlet, rear
Clock positions = 12 o'clock or 0° = top. 3 o'clock or 90° = right side. 6 o'clock or 180° = bottom. 9 o'clock or 270° = left side.

BACKGROUND

A unit operation limit of 720 deg. F exhaust gas temperature (T6) is imposed by Curtiss Wright on the MOD POD 25 and 50 generating sets due to internal bolt failures and turbine stator housing problems (Reference SIB 60 dated 1984). This power level is often referred to as a 20MW limit. **Newfoundland & Labrador Hydro** (NL&H) upgraded their Mod Pod 50 units in 1988 with newly redesigned power turbine housings and other modifications by Fern Engineering. These modifications removed the restriction on their units.

In 1995, **Newfoundland Power Company (NPC)** purchased the old, used and replaced NL&H power turbine casings from NL&H. The casings were inspected, minimally weld repaired (Ref. PIB 1059), and installed at Grand Bank to replace the **NPC** stator housings which had severe cracks and distortion. This, of course, did not remove the operational limits imposed by SIB 60 or TIB 002. The Grand Bank unit has been operating under the limits thus imposed. This year, 2002, a limited general inspection of the gas turbine was scheduled, as well as other concerned areas, to determine if any deterioration of the gas turbine had occurred since the used cases were installed. The inspection was also to be a guide in continued operation.

CONCLUSIONS

1. Records indicate unit utilization since last inspection in 1995 exceeded the start limitation of TIB 002 and the time limitation of SIB 60. Therefore, bolt Part Number 181647 (Fern No. 5054-26-1510P3) (36 @) and tablock washers 5054-26-1524P3 (18@) need to be replaced prior to further operation.

2. With the exception of (1) above, inspection results did not reveal any other deterioration that would preclude continued operation within the limits of SIB 60 or Fern TIB 002.

3. The turbine rotor front labyrinth seal shroud, P/N 181327, exhibited moderate to heavy rubbing at the lower left quadrant (180 - 270 deg.). See Sketch 3.

4. The GG high-pressure air bleed for PT cooling has been over bleeding because there was no orifice installed.

5. Gas Generator to Power Turbine inlet housing bellows alignment is satisfactory.

6. Turbine exhaust stack (down stream of the exhaust volute) is severely deteriorated.

7. Exhaust volute rear support spring packs load settings were set higher than recommended.

8. Inlet filter house down stream of the filters is in excellent condition.

9. CWC PIB 1020A (ref. RR MOD OLP 4035), Relocation of the GG vibration pickup had not been incorporated.

10. On site Maintenance Manuals and service bulletins are incomplete and deteriorated from handling.

RECOMMENDATIONS

1. Replace support bolts (181647) and tablocks 5054-26-1524P3 during assembly and prior to further operation.

2. Comply with the 720 Deg C (1328 Deg F) power limit of SIB 60 and the 140 start limitations of TIB 002 to schedule the next inspection cycle.

3. Set volute spring pack load settings to recommended values. (Completed)

4. Relocate GG vibration pick up to PIB 1020A location. (Completed)
   Ensure pickup is rated for a hot environment of 500F or more.

5. Upon re-commissioning, perform a complete vibration survey of the power train.

6. Locally fabricate GG orifice plate per SIB 39 det.13 and install as shown. (Completed)

7. At a future date, incorporate the power turbine engineering changes recommended by Fern Engineering.

8. Repair or replace the exhaust stack.

9. Prior to initial start up, record actual EMF output of the thrust and counter thrust bearing twisted wire thermocouples and compare to ambient temperature in vicinity of the rear bearing metal for evaluation of this type of thermocouple.

10. Reproduce the maintenance manuals and all applicable service bulletins from legible manuals and bulletins for on site use.

DISCUSSION

Condition of unit upon my arrival 7/15/02

As of 7/15/02, the unit was out of commission with the GG disconnected from the power turbine (PT) at the gas generator (GG) end of the expansion joint (bellows). The PT Inlet housing front cover and internal air pipe was removed. The front support diaphragm was removed, laid in the inlet housing inner cone, exposing the 181327 labyrinth seal, which was in position. All insulation blankets were in position. Exhaust Gas Temperature (T6) thermocouples were disconnected at the junction box (JB) but were still in the physical mounted position with stem alignment forward.

Significant counter readings were as follows: (See Attachment 1. "start Permissive Hours")

	7/16/02		6/30/95*	Change
Unit successful starts	2336	Unit starts	1966	370
Engine base hours	1342(17Min)	Base hours	1141.3	201
Engine beak hours	446(10Min)	Peak hours	377.7	68.5

*Fern records from 1995 work report H. Plante, not attached.

If the present record is accurate, the unit has exceeded both temperature (720C/1328F)and numerical start limits (140) of SIB 60 and TIB 002. During discussions with NPC personnel, statements indicated this unit had not been operated as indicated by the record. This statement was accepted to determine the extent of the inspection to be conducted (i.e. Without removal of stator housings unless external cracking noted.)

Stator housings, stator vanes, rotor blades

All blankets were removed and the stator housings cleaned of debris. An external visual examination for cracks was conducted and several suspicious areas dye checked. Only one minor external crack was detected on the lower casing. This was at 9 o'clock at the juncture radius area between the rear of the front flange and bottom of the split line flange. It is considered a surface crack at this time.

The gas path internal area forward of the first stage stator vanes (1st stage vane retaining land) and the area between vane airfoil spaces was visually examined for axial and transverse cracks and/or missing sections. The first stage stator vane air foils and first stage rotor blade leading edges were also viewed for damage (FOD). A few axial cracks of the housing lip were noted. No missing sections or transverse cracking was noted. No FOD was noted. The front internal shroud (PN494055) was checked for intrusion into the gas stream. At 3 o'clock the upper seal had moved into the gas stream approximately 1/8 inch at the split. (See SIB Page 9, Fig. 5, attached. This

type deterioration is expected and CW issued repair bulletin SIB16, 3/18,77. This should be reviewed after another 200 hours of operation.**

The gas path area at the turbine discharge end was viewed for 2nd stage trailing edge FOD. None was noted.

Inlet housing, lug wear, 181327 shroud

Prior to removal of the blankets for inspection of the inlet housing surfaces for cracks, it was noted that the T6 thermocouple blanket aperture fill pads were too small for the aperture thus exposing bare metal sections. See Sketch 1. All blankets were removed and the inlet housing assembly surfaces were cleaned of debris. The surfaces were visually examined for evidence of cracking. Suspicious areas were dye checked. No cracks were detected. The thermocouple mounting boss keyways were examined for damage. All were satisfactory.

The thermocouples were viewed for key orientation and it was found that they had 2 key ways but they did not have any keys. The keyways were oriented with the gas sampling windows. A search for the part number and manufacturer was unsuccessful. Without keys, proper alignment of the gas sampling window with the gas stream can not be assured and the accuracy of the T6 temperatures measurements is in question. Gas sampling window positioning is dictated by Rolls Royce to ensure a correct relationship between GG turbine inlet temperature and Exhaust Gas Temperature (T6). Positioning at specific radial immersion depth and axial alignment is crucial for proper correlation. T6 operating limits are established on this basis as is the Power Turbine design. Without approved thermocouples, actual required operating temperature relationships cannot be assured. The approved thermocouple is CW P/N 181847.

The inlet housing rear outer flange retaining ring is heat distorted at the stator housing split line area. This is typical for this design and the magnitude of distortion increases with higher power levels. **

Inlet housing internal centering lugs were measured for radial wear and axial position gaps and found acceptable. See TIB 003 Page 7, Fit 43 attached.. Radial slots exhibited circumferential sharp edges, which is typical with this design. **

Turbine rotor front labyrinth seal to front labyrinth shroud axial position and radial fits were measured and found satisfactory for continued use. See TIB 003 Page 4, Fits 5 & 6. The shroud (PN181327) was removed to inspect for extent of circumferential wear. A newly worn section appears between 6 and 9 o'clock. See Sketch 3. **

Exhaust volute and exhaust stack

The exhaust volute was visually examined for cracks and distortion. No cracks, distortion, impact marks were noted. SIB 8A installation was inspected for integrity. No problems were noted. The exhaust expansion joint internal deflective ring is in bits and pieces. Several loose pieces were removed. Much small debris trapped in the transition duct recess bolting area remains. This area should receive attention, possibly replacement before re-commissioning. The remaining stack details (walls, splitters) are in various stages of deterioration.

The volute rear spring packs were removed, cleaned, and tested on a hydraulic press device with a 3.5 inch piston and a pressure gage. The old set scribe on the packs were not correct, having been set at a heavier support load than required. Load setting should be 1585 pounds dead weight. This relates to a psig setting of approximately 165 psig on the hydraulic press utilized. (Load = piston area x psig = 9.62 x 164.7)
The spring packs were inscribed with this load line and reinstalled. The 4 loading ball bearings were free of spalling and were reused for assembly. See MM pg 2-148 Figure 2-2-4 attached.

Inlet filter house, inlet plenum

The inlet filter house, up stream of the media, was clean but showing signs of rust in a few areas. This should be cleaned up and painted. The down stream side of the media is spotless. The media has recently been replaced. Viewing of the silencer splitters from the inlet filter area indicate all splitters are in excellent condition. The inlet plenum area was not viewed.

Power turbine radial bearings, thrust and counter thrust bearings, and associated thermocouples

The front bearing cover and the front bearing were not removed. The rear bearing cover and bearing cap were removed to gain access to the thrust and counter thrust bearings and thermocouples. The front bearing oil supply pipe was visually checked for integrity and was found to be in good condition.

The thrust/counter thrust bearing thermocouple channel RTV was removed. A continuity check for each thermocouple indicated an open circuit between the terminal block and the pads. The thrust and counter thrust bearings and carriers were removed. The thermocouples were drilled out and new hand made (twisted wire) thermocouples were installed and epoxied in place. A continuity check indicated positive and an emf check indicated generation. As the twisted wire thermocouple presents multiple junctions in series along a length (rather than a single point), the resulting emf output will be an average of the length exposed to temperature variations. This should not cause a problem as alarm and trip functions are the main feature of these thermocouples vs. operational evaluation numbers. The thrust and counter thrust bearing pads and carrier were reinstalled and the wires connected to the terminal block by normal soldering. This connection is normally silver soldered. The wire channel was filled with RTV sealant.

The front and rear radial bearings were not removed nor were clearances checked. As the unit has experienced random vibration shut downs, it was suggested that the rear bearing be removed and inspected for unusual wear patterns. This request was denied due to calendar timing for on site work. This should be done when time permits.

The front and rear radial bearing thermocouples and the oil drain thermocouple were removed for inspection purposes.

With the exception of installing the thrust and counter thrust bearing assembly, none of the above removed items were re-installed prior to my departure.

Gas generator to Inlet housing alignment.

The factory alignment is repeated to some extent in the field during module alignment procedures. Final alignment of the GG to the inlet housing is accomplished as explained in the power train outline drawing. A copy is provided in the maintenance manual and has been utilized at Grand Bank recently. The difference is that originally, all assemblies are zero time at initial installation with no deformation of assemblies. Subsequently, all assemblies have bean subjected to operating time and temperature degradation and resultant deformations.

The alignment of the GG exhaust case to the PT inlet case front flange to accommodate bellows misalignment, although spelled out in the maintenance manual, is all but impossible with the original inlet housing design. In order to accommodate thermal growth, the outer rear mounting flange was designed with a serrated type growth ring. At cold position, the housing sags approximately 3/16". During operation, this droop changes and by design is supposed to be centralized. In addition, accumulative operating stresses cause housing rear flange bending and inner and outer duct distortions. **

Several years ago, NPC checked and adjusted the GG to a new position, in accordance with the maintenance manual. This resulted in the GG front end being lowered so that the centralization of the GG inlet flare in the inlet plenum door changed. The GG is now off center and low by approximately 1.5 inches. A new offset rubber seal will have to be constructed and installed to seal the plenum area from the GG area. All trunnion mount shim plates had been removed.

Rear trunnion mount dowels had been relocated. Therefore, it was decided to repeat alignment checks with the expansion joint removed.

GG alignment to inlet housing check

As the GG had not been removed from the module and was suspended from the overhead rail system, a proper XYZ alignment with the rotor bore was not possible. This was a moot point anyway as GG exhaust to Inlet alignment per MM power train outline drawing, was to be the criteria followed. In essence, this means that the inlet housing position dictates the final position of the GG. Therefore, the first step was to establish whether or not all mounts were in proper relation to each other in axial (X) and transverse (Y) spacing. The GG itself was utilized as the fixture for this check. The GG was lowered into the front trunnion mounts and the caps were installed. This ensured both an X and Y starting point. The GG was then lowered at the rear until both rear trunnion mount axles could simultaneously be inserted into vertically centered resilient bushings.

The resilient bushing carriage adjusts laterally through its growth/slide design. Once seated the gap between the bushing and the rear mount is measured to ensure the engine is centrally located laterally. The GG mount radial gaps were measured and the results indicated that the GG was central to the mounts per MM power train outline drawing. See Sketch 4B.

With the GG suspended such, flange to flange parallelism (angular) and the axial distance between the GG and the PT inlet housing was checked by measuring the axial distance between the GG exhaust rear face and the inlet housing front flange front face at 4 clock locations (12,3,6,9 o'clock) utilizing a fixed gage and an inside micrometer. The distance was larger at 6 o'clock (0.086") and at 9 o'clock (0.006'). The average axial distance between flanges measured 16.359

inches. This distance should be 16.229 inches. This indicates the mounts to be located slightly forward of drawing requirements.

Installation of a short expansion joint (length when new of 15.197 inches) and a 0.562 inch shim plate does not totally fill the 16.229 inch axial distance between the GG and the inlet housing leaving a 0.472 gap that results in prestretching the expansion joint by this amount. In this case, the actual gap with the bellows installed and the GG in place may present a different gap as the actual length of this particular bellows is unknown.

The bellows was not reinstalled before my departure so the actual gap or the axial parallelism could not be measured. However, when I first arrived on site the bellows was in place then and the gap appeared reasonable but it was not measured.

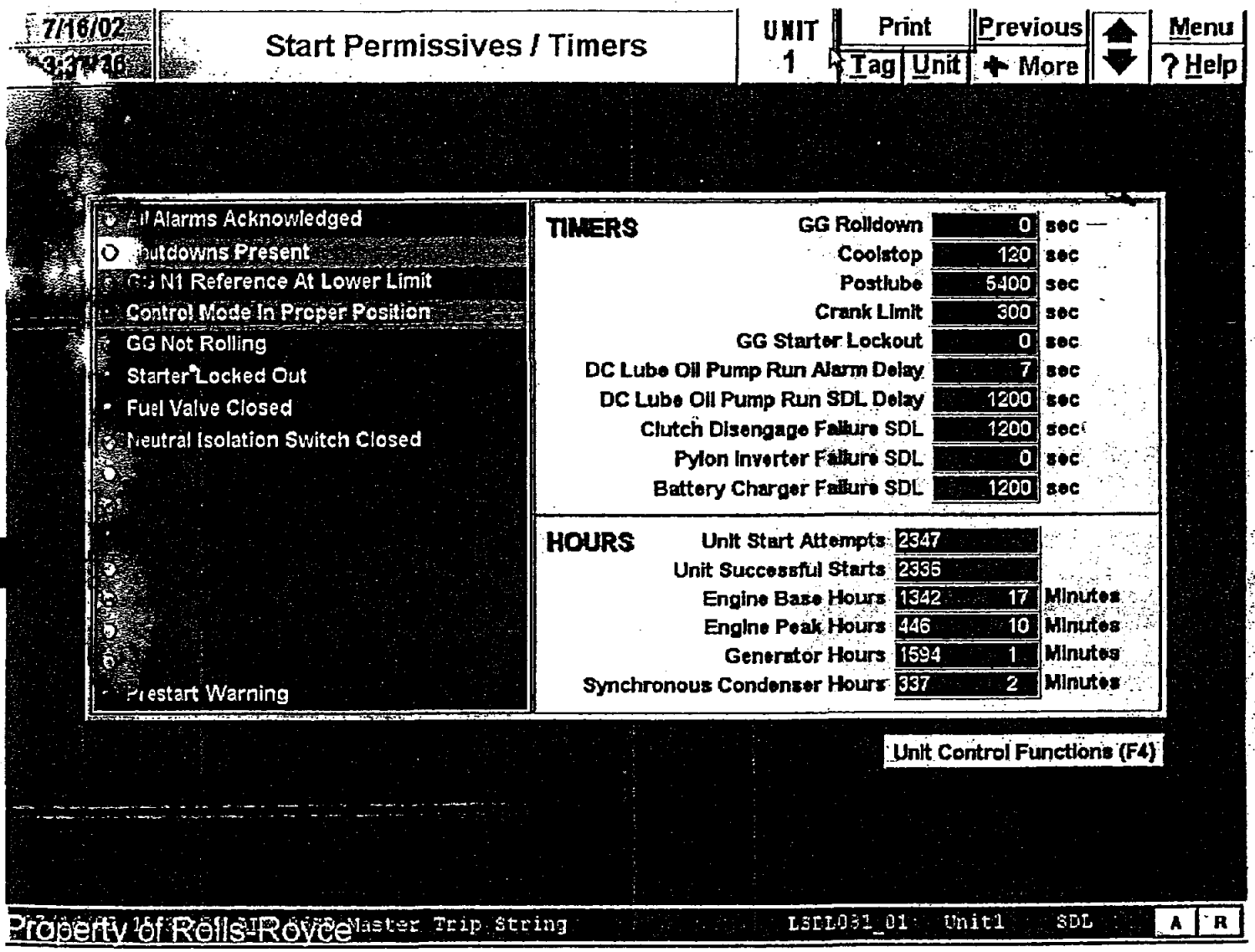
A rough diagonal length measurement from the top of the GG to the bottom of the inlet housing with a tape measure and a similar measurement side-to-side indicated the centers are within 1/32" inch to each other which is minimal and acceptable. See Sketch 4A. This whole area will have to be revisited any time there is an expansion joint replacement **

GG vibration

During a casual overall look at the GG, it was noted that the vibration pick up was located at the original CW selected location. Subsequently, Rolls Royce issued a bulletin to relocate the pickup to a different location that was in accordance with their standard test stand location at the front of the delivery case. See Page 2, Figure 1, PIB1020A, attached. A vibration pick up for this higher temperature area was also recommended. After pointing this bulletin out to John Budgell, the bracket and pickup was moved to the new location. The current pick up must be checked to verify if it is satisfactory for a potential temperature of approximately 500 F. Following re-commissioning, a complete power train vibration survey will quantify this new location.

****Fern engineering design changes address these areas.**

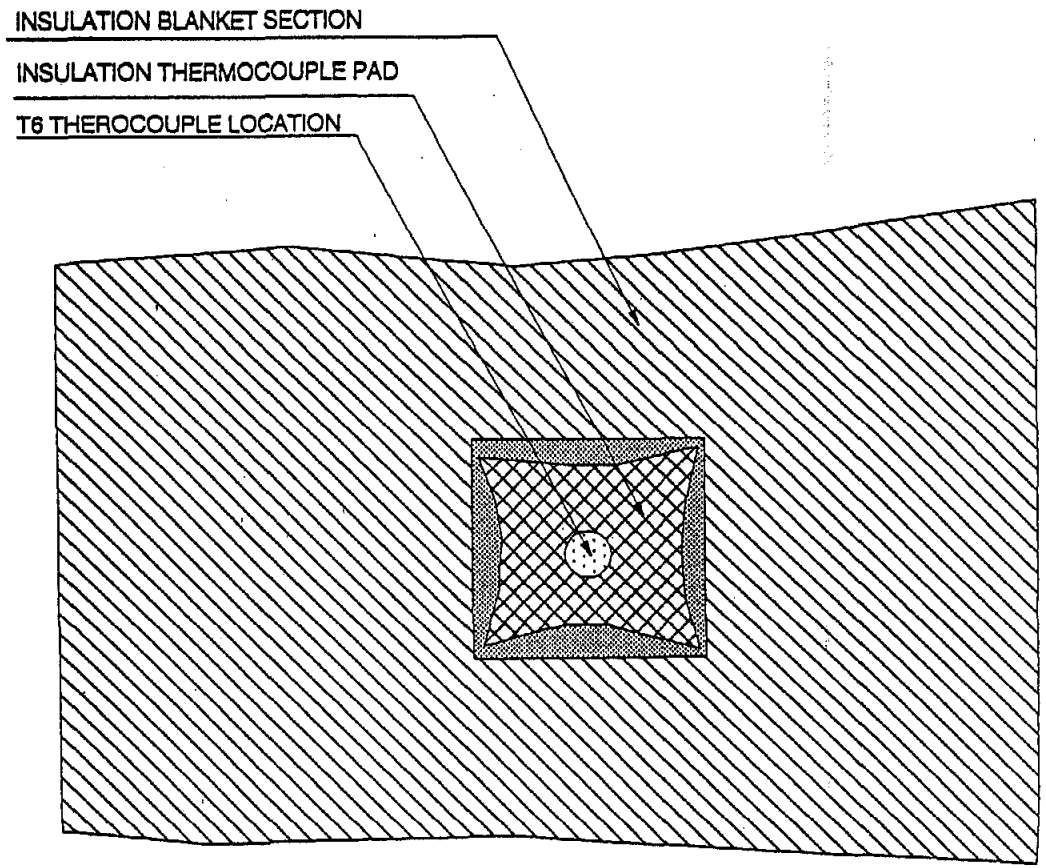
ATTACHMENTS



Property of Rolls-Royce

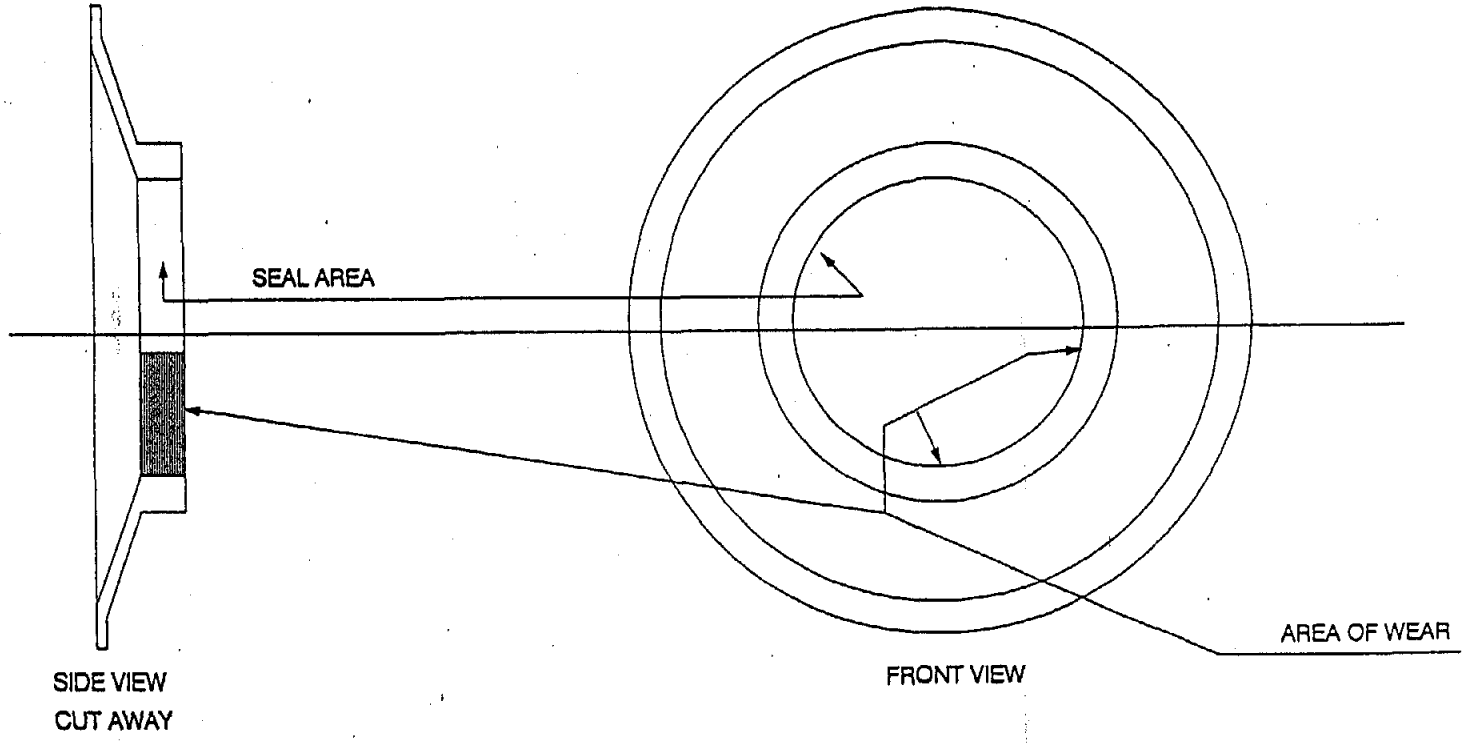
ATTACHMENT 1.

T6 THERMOCOUPLE PAD DISTORTION IN BLANKET APERTURE

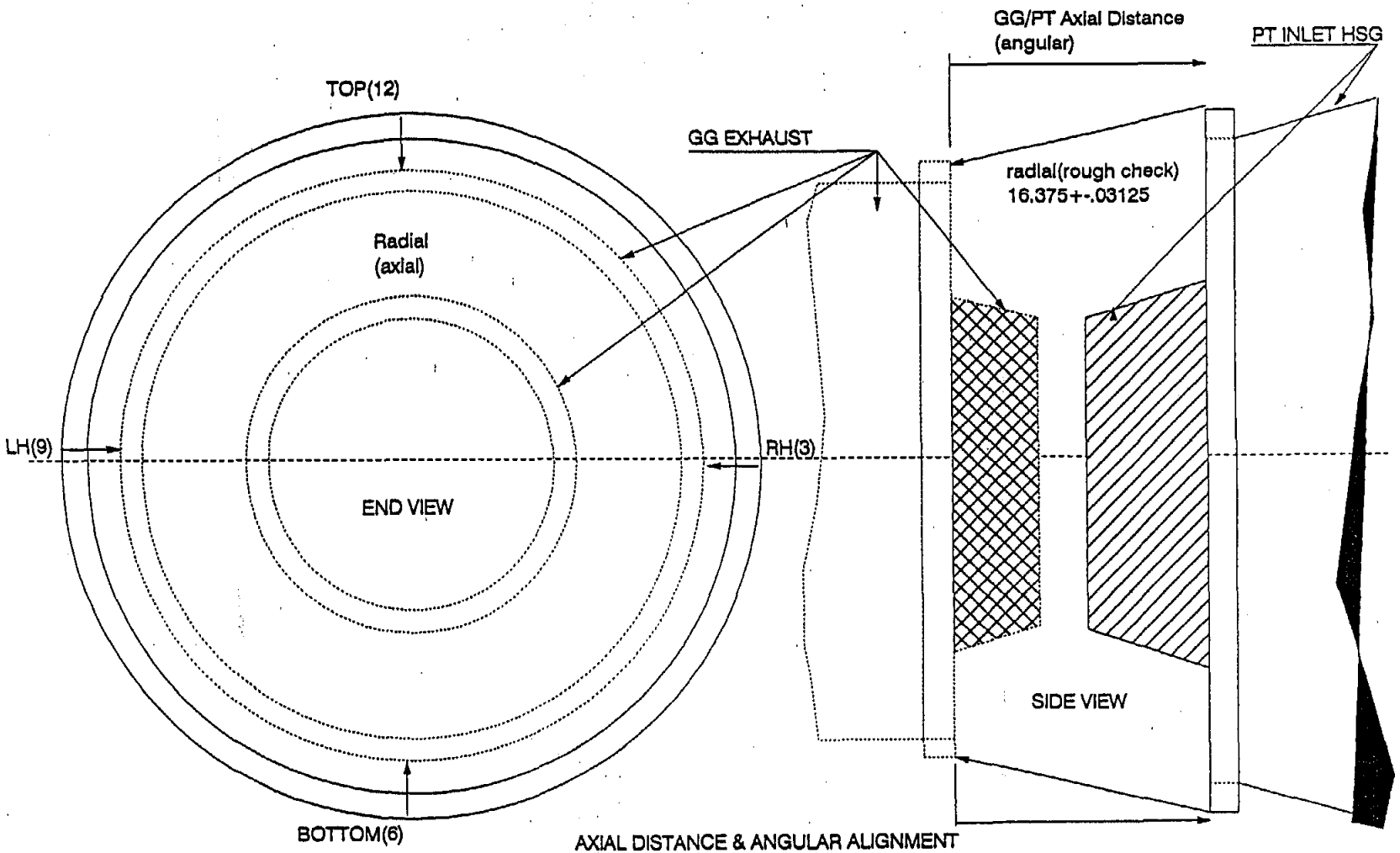


NPC GRAND BANK
REPORT 6574-08-3
SKETCH 1

181327 STATIONARY PT FRONT LABYRINT SEAL WEAR



NPC GRAND BANK
REPORT 6574-08-3
SKETCH 3



AXIAL DISTANCE & ANGULAR ALIGNMENT
DRAWING BASIC DISTANCE 16.229+/- .059
ACTUAL BASIC AVERAGE= 16.359"

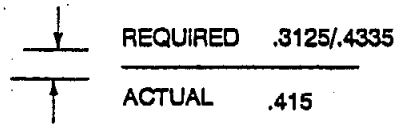
CLOCK	MEASUREMENTS(+/- FROM GAGE)	DEVIATIONS
12		=+.002"
3		=+.053"
6		=+.059"
9		=+.088"

Alignment of GG Exhaust to PT Inlet Housing

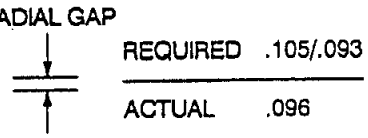
NPC GRAND BANK
REPORT 6574-08-3
SKETCH 4A

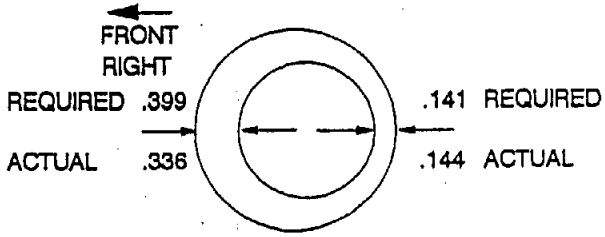
NPC Grand Bank

ALIGNMENT CHECK OF GG MOUNTS
FRONT MOUNT CAPS INSTALLED
REAR TRUNNION AXLES CENTERED VERTICALLY
AXLES FREE TO SLIDE IN AND OUT
GG REAR WEIGHT SUPPORTED CENTRALLY
AIRCRAFT CONVENTION
RADIAL GAPS VIEWED FROM TOP
REAR TRUNNION AXIAL GAPS SIDE VIEW

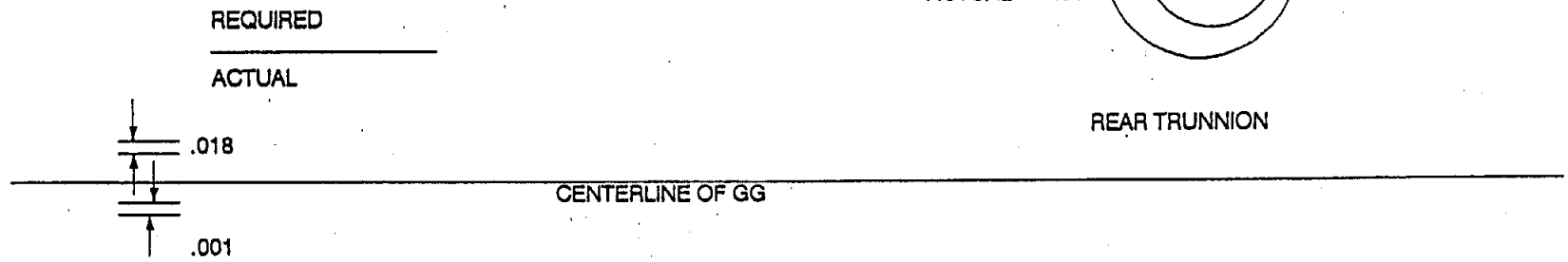


FRONT TRUNNIONS
RADIAL GAP
RIGHT SIDE

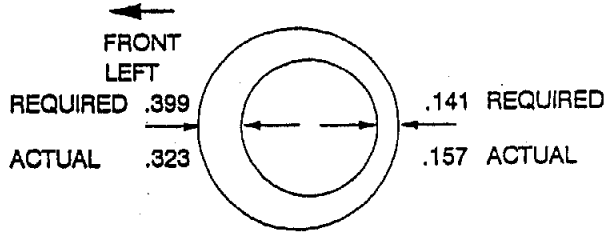


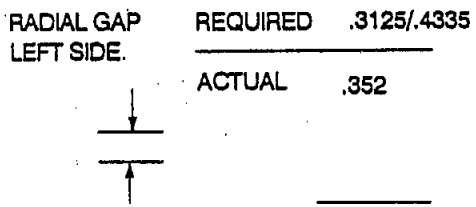


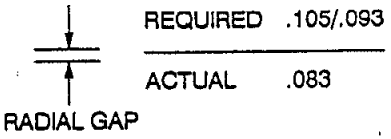
REAR TRUNNION



FRONT CENTERING MOUNT
SIDE GAP







REAR TRUNNION

REPORT 5467-08-3
SKETCH 4B

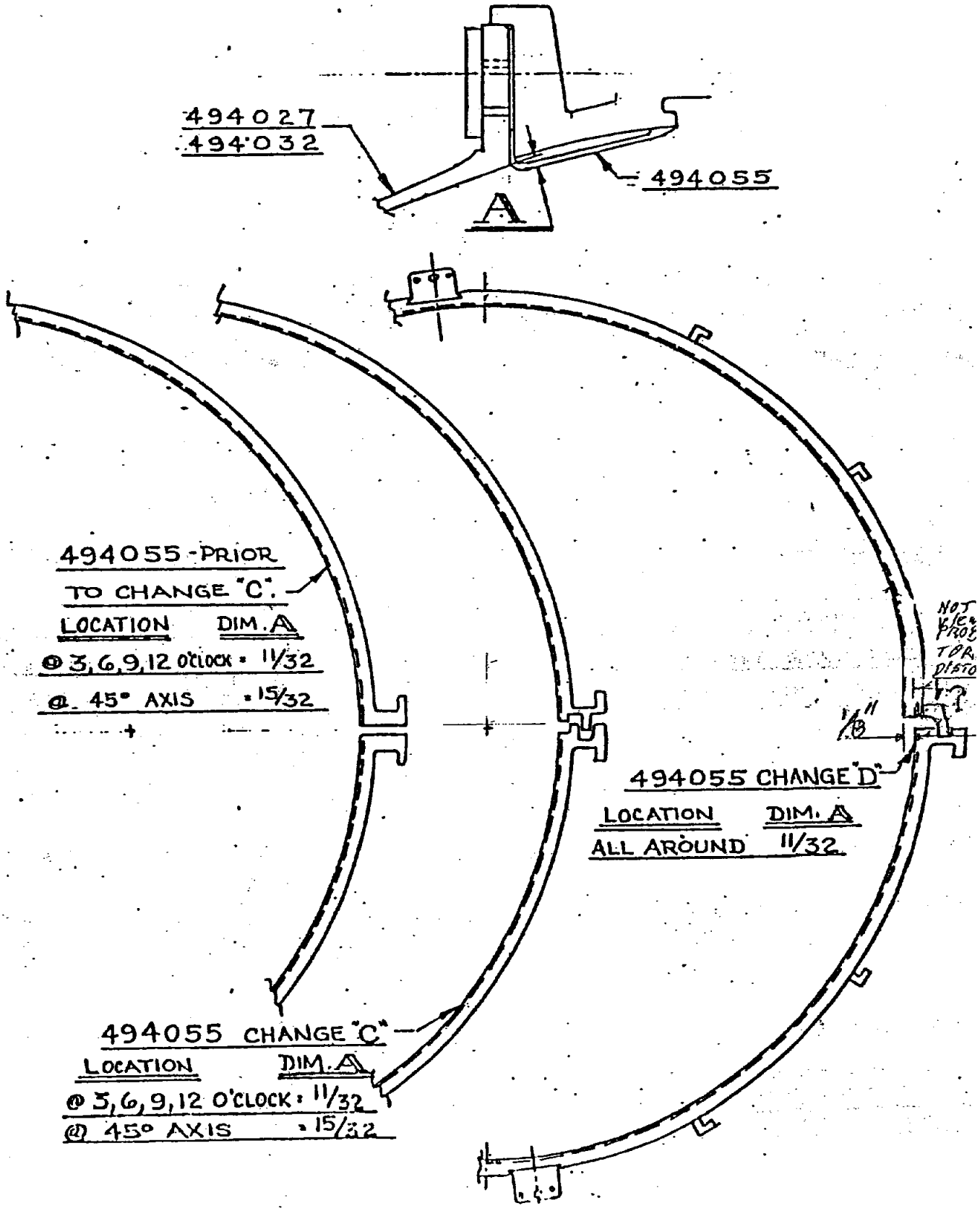
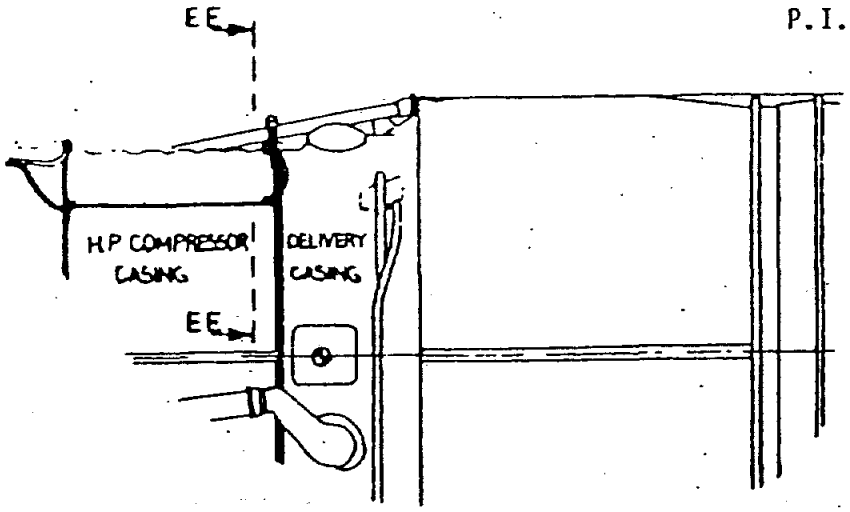
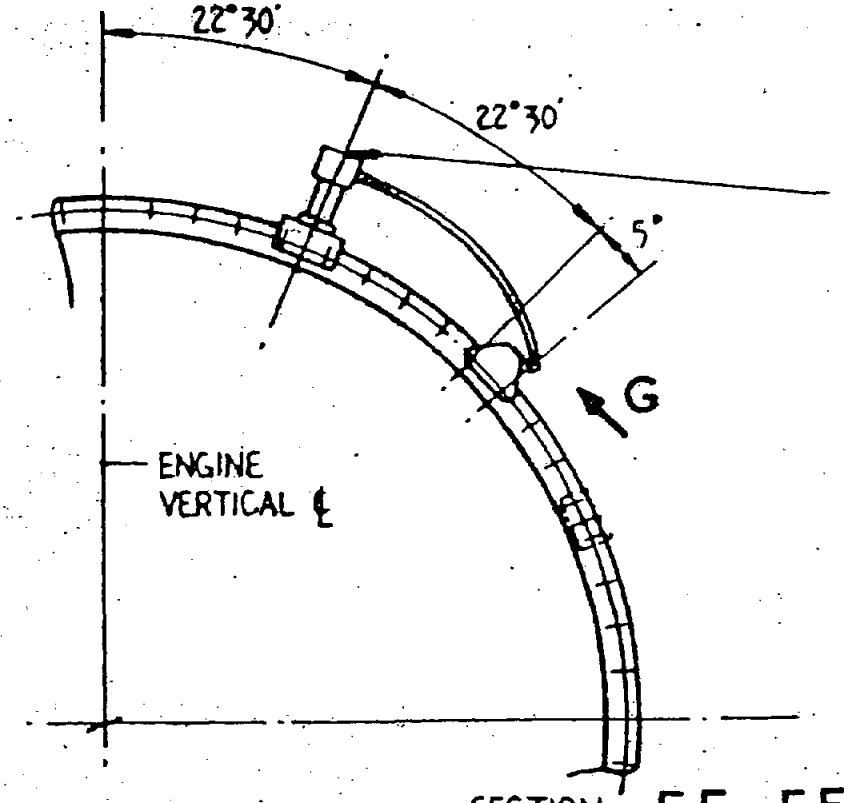

494027
494032
494055
A
494055 - PRIOR TO CHANGE "C".
LOCATION DIM. A
@ 3, 6, 9, 12 O'CLOCK = 11/32
@ 45° AXIS = 15/32
494055 CHANGE "C"
LOCATION DIM. A
@ 3, 6, 9, 12 O'CLOCK = 11/32
@ 45° AXIS = 15/32
494055 CHANGE "D"
LOCATION DIM. A
ALL AROUND 11/32
1/8"

Figure 5

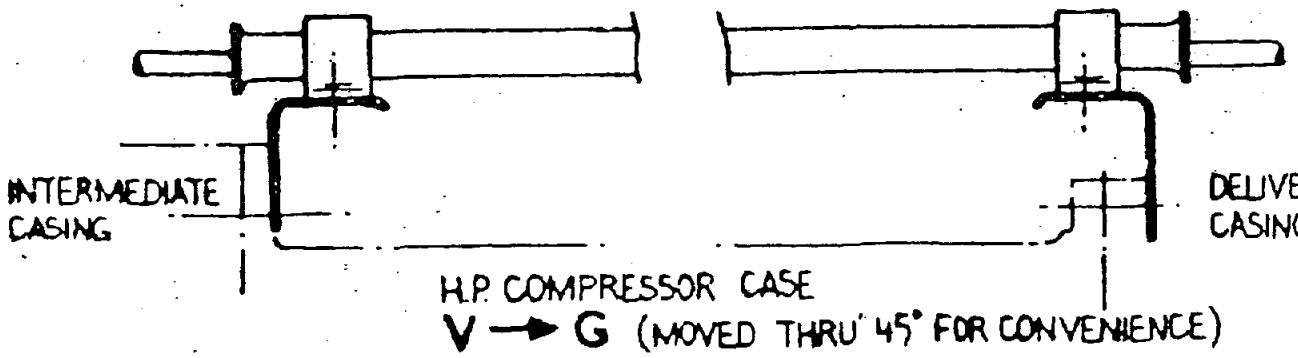


PART VIEW ON PORT SIDE OF ENGINE



POSITION OF VIBRATION TRANSDUCER & BRACKET - AFTER MODIFICATION

SECTION E E - E E
SHOWING POSITION OF TRANSDUCER & BRACKET



INDEX NO.	NOMENCLATURE	PART NO.
1	SCREW	125D231
2	PAD	181355N2
3	PAD	181355N3
4	BALL	MS19060-36
5	SUPPORT	494007

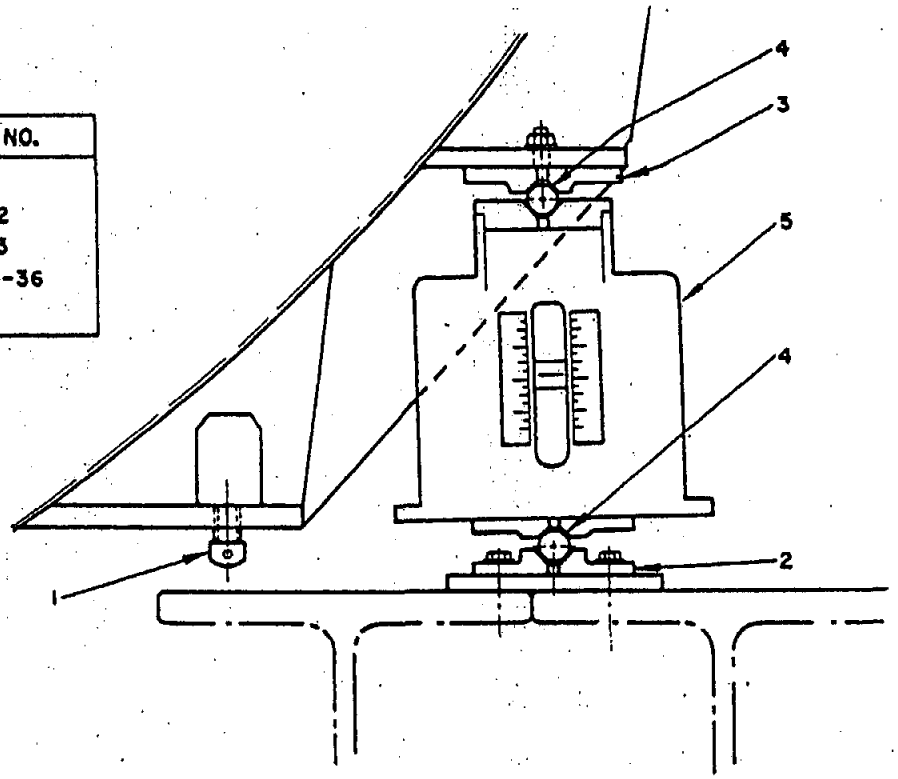


Figure 2.2-4 Volute Mount Supports

FERN ENGINEERING
"The Power Solution"

Table Of Limits
Model CT-2 Power Turbine

NP

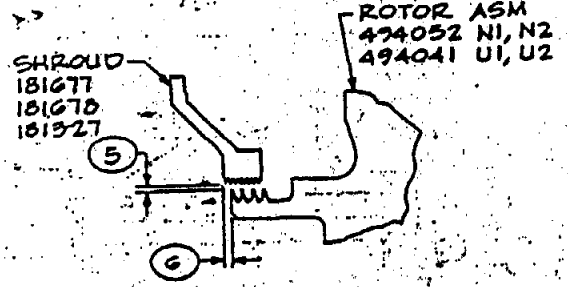
TECHNICAL INFORMATION BULLETIN

55 PONTSIDE DRIVE P.O. BOX 3000 POCASSET, MA 02559 TEL.(508) 563-7181 FAX.(508) 564-4581

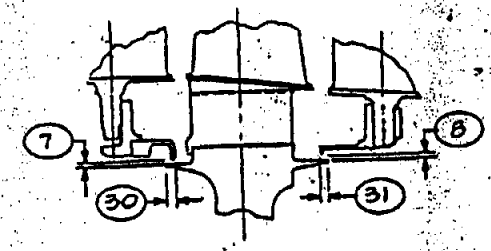
JULY 2002 TIB NUMBER 003

LOCATION GREEN HILL UNIT NAME OR NUMBER MP25 DATE — PAGE 1 OF 3

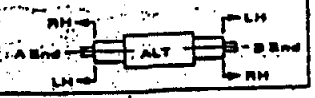
Rev	Fit Number	Description	Max/Min B/P Fit	Max/Min Serv Fit	1st End LH	1st End RH	2nd End LH	2nd End RH
			±.01 / .033/.013	±.01	.065 L .087 T .057 R .050 B		L T R B	
1	5	First stage turbine rotor disk to labyrinth seal (.013 Min. at Bottom) Rad. Gap diameter difference = shroud ID − rotor labyrinth OD = .140 (Serv Fit) .110 (B/P Fit) (Preassembly dimetrol measurement)						
	6	Labyrinth seal to first stage turbine rotor disk front Axial overlap	.137 .000	.137 .000	+.020			
	7	First stage turbine rotor disk to front air seal Radial gap	.115L .090L	.125L .090L				
	8	First stage turbine rotor disk to rear air seal Radial gap	.115L .090L	.160L .080L				
	30	First stage turbine rotor disk front to front air seal Overlap	.298 .113	.435 .113				
	31	First stage turbine rotor disk rear to air seal Overlap	.273 .094	.280 .030				



FRONT ROTOR SEAL CLEARANCE



ROTOR DISK AIR SEAL CLEARANCE



FERN ENGINEERING
The Power Solution

Table Of Limits
Model CT-2 Power Turbine

TECHNICAL INFORMATION BULLETIN

56 PORTSIDE DRIVE P.O. BOX 3360 POCASSET, MA 02559 TEL.(508)563-7161 FAX.(508)564-6661

TIB NUMBER 003

LOCATION _____ UNIT NAME OR NUMBER _____ DATE _____ PAGE 7 OF 8

Rev	Fit Number	Description	Max/Min S/P Fit	Max/Min Serv Fit	Axial LH	Axial RH	Radial LH	Radial RH
	20	Inlet housing centering ring to stator housing (Curtiss Wright Design) Dia.	.004L .002T					
	20	Inlet housing centering ring to stator housing (Fern Modification) Dia.	.012L .004L					
	21	Power turbine mount support to stator housing (Curtiss Wright Design Dia.	.006L .002T					
	21	Power turbine mount support to stator housing (Fern Modification). Dia.	.012L .004L					
	22	Inlet housing to inlet housing centering ring. Linear — Not applicable with Fern modification	.006L .001L	.007L .001L				
	42	First stage vane inner shelf front to inlet housing inner rear flange Gap — ~~FIT~~ MEASUREMENT ONLY CANNOT BE GAGED	.161 .033	AXIAL .215	AXIAL .117	AXIAL .131	AXIAL .128	
	43	Inlet housing ring lug to first stage turbine stator expansion ring lug. Gap — Not applicable with Fern modification	.191 .097	CIRC UNIFORM RADIAL .020			.020	
	54	Terminal support bracket to bearing support split line Gap	.003 .000					

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